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926.1008

UNITED STATES PATENT AND TRADEMARK OFFICE

Re:	Application of:	Guy CLAVAREAU, et al.
	Serial No.:	Not yet known
	Filed:	Herewith
	For:	METHOD FOR MAGNETRON SPUTTERING

LETTER RE PRIORITY

Commissioner for Patents
P. O. Box 1450
Alexandria, VA 22313-1450

April 20, 2005

Dear Sir:

Applicants hereby claim the priority of Belgian Patent Application No. 2002/0606 filed October 23, 2002 through International Patent Application No. PCT/BE03/00179 filed October 22, 2003.

Respectfully submitted,

By: Dona C. Edwards

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DECLARATION

I, the undersigned **DOMINIQUE DELBECQ**, having a degree in translation, do hereby declare that the enclosed document entitled « ASSEMBLY FOR MAGNETRON SPUTTERING S.A. » is a true and complete translation of Belgian patent application n° 2002/0606 filed on October 23, 2002 in French language.

Signed this April 1, 2005

Delbecq

Dominique Delbecq

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BIC (SWIFT): BBRUBEBB
IBAN: BE22 3100 2045 3447

KINGDOM OF BELGIUM

It is certified that the annexes to the present document are the true copy of the documents accompanying a Patent Application such as filed in Belgium according to the comments of the annexed report of filing.

Brussels, 22-10-2003

For the Director of the Industrial Property Office

The delegated official,

MINISTERE DES AFFAIRES ECONOMIQUES

REPORT OF FILING OF A PATENT APPLICATION

ADMINISTRATION DE LA POLITIQUE COMMERCIALE
Office de la Propriété Industrielle

N° 2002/0606

Today, 23-10-2002, in Brussels

clock: 10.30

Mrs Hondius Barbara

Acting as
- Applicant
- Employee of the applicant
- Employee of an effective company of the applicant
- Authorized attorney
- X Employee of the authorized attorney, **Mr. D. CAUCHIE**
- Layer

Comes to the INDUSTRIAL PROPERTY OFFICE to file an application in order to obtain a patent with respect to an ASSEMBLY FOR MAGNETRON SPUTTERING.

Requested by: **ALLOYS FOR TECHNICAL APPLICATIONS S.A.**
Rue du Chêne, 42A
5590 ACHENE-CINEY (Belgique)

The application, such as filed, contains the necessary documents in order to obtain a date of filing according to the article 16, 1st paragraph, of the law of March 28, 1984 on Patents.

The applicant,

The delegated official,

Brussels, 22-10-2002

ASSEMBLY FOR MAGNETRON SPUTTERING

The present invention relates to an assembly intended to magnetron cathodic sputtering.

In particular, the invention is concerned with an assembly intended to magnetron cathodic sputtering comprising a sputtering target.

The well-known method for coating a substrate with a thin pellicle of material consists in sputtering said material when a difference of potential of several hundred volts is applied between two plates within a chamber filled with a gas at a pressure of about 0,3 to 7 pascals.

The gas, generally a rare gas such as neon or krypton, usually argon, is ionised to this pressure under the action of an electric field and the positive ions so formed bombard the cathode causing the transport of material from the cathodic sputtering target to the anodic substrate.

A classical cathodic sputtering cathode is generally made of a polar basis plate, on the centre and circumference of which permanent magnets are placed, the central magnets being of reversed polarity in comparison with the one of the lateral magnets.

Moreover, a cooling plate is placed between the magnets and the target, the cooling being direct or indirect. On the other hand, given their sensitivity to heat, the magnets are cooled thanks to a water circuit.

The so placed magnets create a magnetic induction which, once coupled to the existing electric field, allows the increasing of the electron pathway so as to locate the plasma on the level of the target. This

confinement is important because it allows the increasing of the deposit speed during the cathodic sputtering of the target and it is maximum when the electric field and the magnetic induction are perpendicular, that is to say when the magnetic induction is parallel to the target.

However, given the shape of the magnetic induction caused by the magnets and its lack of uniformity, the space where this magnetic induction is parallel to the target is very limited and the density of the produced plasma is not uniform, leading to different sputtering rates on the target surface as well as to a typical V-shaped and race-track shaped wearing. In the best instance, only 30% of the target can be used.

In order to enhance the sputtering rate, it is thus necessary to modify the distribution of the magnetic induction so as to enhance the erosion uniformity of the target.

Different solutions have been proposed, most of them consisting in modifying the fixed cathodic assembly.

As an example, it is described in US Patent N° 4 198 283 a magnetron cathodic assembly including among others a sputtering target which has been modified by the addition of polar pieces fixed to the target support plate, these polar pieces being intended to emphasize the curvature of the magnetic field in the shape of a closed loop above the target surface.

Likewise, British Patent, GB 2209769, describes a sputtering system which means for inducing a magnetic field include a magnetic material extending in the direction of the anode beyond the surface supporting the target on its side situated distant from the anode. This polar material is separated from the circular target by means of an aluminium ring.

In addition, an article extracted from the "38th Annual Technical Conference Proceeding", page 414, discloses a method for increasing the performance of plane targets, intended to magnetron sputtering, by the use of a linking ferromagnetic piece placed between the magnet assembly and the target so as to favourably modify the magnetic field on the level of said target surface.

All the above-mentioned methods require the addition of modifications which sometimes can be very important as regard to the fixed sputtering means represented by the magnetron, in particular the fixed cathodic assembly. Given that these modifications have to take into account not only the magnetron characteristics but also the properties of the target used, any change of these properties could render useless these modifications and could eliminate all the advantages researched with respect to the target erosion.

The objective of the present invention is to offer an assembly intended to magnetron cathodic sputtering comprising a sputtering target for overcoming the inconveniences of the state of the art and more particularly for avoiding modifying the fixed assembly of the magnetron.

To achieve this objective, the assembly of the above-mentionned type is characterized in that it comprises, in addition to the sputtering target, at least one ferromagnetic piece inserted into said target or juxtaposed thereto and in that it is configured so as to modify the magnetic induction generated by the magnetron at the level of the target sputtering surface.

According to an additional embodiment of the invention, the assembly is configured so as to modify the curvature of the magnetic induction lines.

Yet, according to another embodiment of the invention, the assembly is configured so as to reduce the curvature of the magnetic induction lines, in particular so as to increase the parallelism of these induction lines at the level of the target sputtering surface.

According to a particularly preferred embodiment, the ferromagnetic piece is completely or partially inserted into the target.

Said ferromagnetic piece, belonging to the method according to the invention, is made of a material permeable to the magnetic field such as steel, soft iron or a soft magnetic alloy ("PERMALLOY®"), for example an iron-nickel alloy optionally including another metal such as molybdene.

Depending on the case, this polar piece can be completely or partially inserted into the target in place of an extracted portion of said target. In any event, this extracted portion is totally replaced by the corresponding portion of a ferromagnetic piece.

When the target is made of a low melting point material such as zinc, the ferromagnetic piece(s) will be inserted or juxtaposed, preferably and as far as possible, to the ends of this target, in order to maintain an efficient cooling of said target and avoid its liquefaction.

On the other hand, the ferromagnetic piece, when it is inserted into the target, may also be an indicator of the end of use of this target once its erosion has reached said ferromagnetic piece.

As for the target, it can be of different shapes such as circular or rectangular and be endowed or not with round angles.

The invention also offers a process for manufacturing the assembly intended to magnetron cathodic sputtering according to the invention, characterized in that:

- <u>either</u>

a ferromagnetic piece is completely or partially inserted into the target after extraction, at a predetermined location of this target, of a portion thereof which is replaced by an equivalent portion of the said ferromagnetic piece

- <u>or</u>

a ferromagnetic piece is juxtaposed to the target at a predetermined location thereof.

The insertion or the juxtaposition of the ferromagnetic piece is carried out after having predetermined not only the location but also the shape and the size of this piece, according to the desired modification type at the level of the magnetic induction initially generated by the magnetic circuit of the magnetron.

Generally and preferably, this predetermination of location, shape and size is carried out thanks to a bidimensional or tridimensional modelling of the magnetic induction which is obtained by means of an adequate software-assisted computer technique.

This modelling allows the visualisation of the magnetic induction geometry, the magnetic induction itself and the magnetic induction lines previously calculated. This modelling is then validated by comparing the calculated values for the magnetic induction with the corresponding measured values.

When the desired modification consists in a curvature increase of the magnetic induction lines at the

level of the target sputtering surface so as to increase the parallelism of these induction lines, the modelling of the vertical component of the modelled induction is also validated by comparing the calculated values for said vertical component with the measured corresponding values.

In a further step, a virtual ferromagnetic piece is inserted into the modelled magnetic induction and the desired modification of the magnetic induction is searched by translation of said modelled induction in order to increase the curvature of the magnetic induction lines at the level of the sputtering surface of the virtual target integrated in the modelling, or in another way, in order to decrease the value of the vertical magnetic induction component, i.e. Bz.

Given that the addition of this ferromagnetic piece decreases the total magnetic induction, i.e. B_{total}, represented by the square root of $(Bx^2 + By^2 + Bz^2)$ at the place of insertion into the target or juxtaposition thereto, it is possible to optimise the location, shape and size of this piece in the modelled induction.

In other words, when a parallelism increase of the magnetic induction lines above the target sputtering surface is searched, the main goal of this optimisation is to select the magnetic induction area(s) where the value of the parameter $\frac{Bz}{B_{total}}$ is the lowest while keeping a sufficient magnetic induction for a sufficient confinement of the electrons at the target sputtering surface, usually an induction equal to at least 100 gauss.

When this parameter is equal to zero, the magnetic induction lines are perfectly parallel to the target and, if it is equal to one, those lines are quite vertical.

It is then necessary to find on the real sputtering target the optimised position for the settlement of the real ferromagnetic piece which shape and size are so defined and to proceed to the insertion or juxtaposition of said piece.

This insertion is usually carried out according to known techniques after extraction, by cutting up, of the necessary portion of the target and consists in replacing said portion by an equivalent portion of a ferromagnetic piece which shape has been obtained especially by manufacture.

As regard to the juxtaposition of the ferromagnetic piece to the sputtering target, it is generally carried out according to a known method, for example by sticking.

Taking the above into account and according to one of its particular aspects, the invention relates, as a consequence, to a process for manufacturing an assembly according to the invention, characterized in that it consists in:

a) determining, by measuring, the values of the total magnetic induction generated by the magnetron,
b) modelling, by means of a software-assisted computer technique, the magnetic induction from the magnetron physical characteristics,
c) comparing the modelled values of the magnetic induction with the previously measured values,
d) searching, in this modelled magnetic induction, the location, shape and size of a virtual ferromagnetic piece able to modify, in the desired manner, the

magnetic induction at the level of the target sputtering surface,

e) optimizing the searched location, shape and size,

f) adding to the sputtering target and at the determined location, a ferromagnetic piece corresponding to the shape and size data so defined this being carried out either by insertion into that target or by juxtaposition thereto.

According to an additional embodiment of the process according to the invention, the searched location, shape and size for the ferromagnetic piece are optimized thanks to the parameter $\frac{Bz}{B_{total}}$ when the modification of the magnetic induction consists in increasing the parallelism of the induction lines at the level of the target sputtering surface.

Therefore, and according to one of its particular aspects, the invention relates to a process for manufacturing an assembly according to the invention for reducing the curvature of the magnetic induction lines and increasing the parallelism of these induction lines at the level of the target sputtering surface, characterized in that it consists in:

a) determining, by measuring, the values of the total magnetic induction generated by the magnetron, and of the vertical component of this magnetic induction,

b) modelling, by means of a software-assisted computer technique, the magnetic induction from the magnetron physical characteristics,

c) comparing the modelled values of the magnetic induction with the previously measured values,

d) searching, in this modelled magnetic induction, the location, shape and size of a virtual ferromagnetic

piece able to reduce the magnetic induction lines and to increase the parallelism of these induction lines at the level of the target sputtering surface,

e) optimizing the searched location, shape and size, thanks to the parameter $\frac{Bz}{B_{total}}$,

f) adding to the sputtering target and at the so determined location, a ferromagnetic piece corresponding to the shape and size data so defined, this being carried out either by insertion into that target or by juxtaposition thereto.

Another object of the invention relates to an assembly intended to magnetron cathodic sputtering when manufactured according to the process of the invention.

Yet, another object of the invention relates to the use of an assembly according to the invention such as hereabove defined, for the formation of a film deposit on a substrate by using a cathodic sputtering process.

Likewise, the invention relates to a film deposit on a substrate, characterized in that the said deposit is formed by using a cathodic sputtering process starting from an assembly according to the invention, such as above defined.

Such an assembly, according to the invention, designed to magnetron cathodic sputtering presents incontestable advantages with respect to the state of the art. Indeed, it allows the increasing of the wearing uniformity of the sputtering target which is a piece of that assembly. This leads to a significant broadening of the erosion area as well as to an attendant reduction of the V-shaped erosion path. As a consequence, given that it is possible to reach an erosion rate of about 70%, the use of the target can be considerably enhanced.

Moreover, the use of such an assembly intended to magnetron cathodic sputtering has also the advantage to avoid any modification of the magnetron but to act only at the level of the target which is a removable element easy to reach on a magnetron.

As a consequence, the invention also relates to a method for uniformizing the erosion at a target sputtering surface intended to magnetron cathodic sputtering, characterized in that an assembly is used which comprises the said sputtering target and at least one ferromagnetic piece which is added thereto, by insertion or by juxtaposition at a predetermined location of that target, that assembly being manufactured by carrying out the following steps which consist in:

a) determining, by measuring, the values of the total magnetic induction generated by the magnetron and of the vertical component of that magnetic induction,

b) modelling by means of a software-assisted computer technique from the magnetron physical characteristics,

c) comparing the modelled values of the modelled magnetic induction with the previously measured values,

d) searching, in this modelled induction, the location, shape and size of a ferromagnetic piece able to reduce the curvature of the magnetic induction lines and to increase the parallelism of these induction lines at the level of the target sputtering surface,

e) optimizing the searched location, shape and size, thanks to the parameter $\frac{Bz}{B_{total}}$,

f) adding to the sputtering target and at the so predetermined location, a ferromagnetic piece

corresponding to the shape and size data so defined, this being carried out either by insertion into that target or by juxtaposition thereto.

The invention will be better understood and other goals, characteristics and advantages will appear clearly through the following explicative description made in conjunction with the attached drawings given as examples illustrating embodiments of the present invention and wherein:

- Figure 1 is a schematic representation of a frontal cut of a sputtering magnetron cathode endowed with a sputtering target
- Figure 2 is a bidimensional graphic representation of the total magnetic induction measured at the fitting surface of the sputtering target
- Figure 3 is a bidimensional graphic representation of the measure of the magnetic induction vertical component illustrated in Figure 2
- Figure 4 is a bidimensional representation of a modelling of the magnetic induction above the sputtering surface of the target illustrated in Figure 1
- Figure 5 is a comparative bidimensional graphic representation of the measure of the total magnetic induction illustrated in Figure 2 and of the calculation of said total magnetic induction
- Figure 6 is a comparative bidimensional graphic representation of the measure of the magnetic induction vertical component illustrated in Figure 3 and of the calculation of said magnetic vertical component
- Figure 7 is a graphic representation of the quotient

$\frac{Bz}{B_{total}}$ for the magnetic induction calculated at the target sputtering surface

- Figure 8 is a bidimensional graphic representation of the modelling illustrated in Figure 3 including a ferromagnetic piece
- Figure 9 is a comparative bidimensional graphic representation of the total magnetic induction calculated at the level of the target sputtering surface with or without ferromagnetic piece
- Figures 10 to 11 are comparative bidimensional graphic representations of a computer simulation of the target erosion with or without ferromagnetic piece.

EXAMPLE 1

On a magnetron endowed with a sputtering cathodic assembly, schematically illustrated in Figure 1, a target 1 has been illustrated which sputtering surface is represented in 2. This target is fixed to a copper plate 3 forming support and maintained on a cooler 4 by means of a clamp 5 whereas a bowl 6 dug from the upper part of the cooler 4 contains a liquid, usually water, intended for the cooling of said plate 2.

The physical characteristics of the magnetron are researched and to this effect, the position of the permanent magnets 7a and 7b and of the cathode ferromagnetic pieces 8 and 9 are located, then the total magnetic induction B_{total} is measured in a conventional way by means of an adequate measuring device. For reasons of accessability, said measure is carried out at the level of the fitting surface of the target 1 on the cooling plate 3. This is carried out from the vertical

central axis z, or vertical symmetry axis, of this cathode on a segment of a line X-X' perpendicular to the axis z and to the longitudinal central axis y, or longitudinal symmetry axis, as well as at different places of said segment, 120 mm length.

The measure of the magnetic induction vertical component, Bz, is carried out in an analogous way.

Figures 2 and 3 represent the magnetic induction curvatures so measured for B_{total} and Bz, respectively.

With the help of an adequate computer software, B_{total} and Bz are calculated thanks to a finite element method and a bidimensional computer modelling of the calculated magnetic induction is carried out as illustrated in figure 4.

This figure shows the modelled geometry of the magnetic induction, the magnetic induction represented by arrows and the magnetic induction lines calculated.

A comparison between the curve representing calculated B_{total} and the curve representing measured B_{total}, illustrated in figure 2, allows the validation of the proposed modelling in figure 5.

An analogous comparison carried out between the curve representing calculated B and the curve representing measured Bz, such as illustrated in figure 3, allows the same conclusion as illustrated in figure 6.

In a further step, a virtual ferromagnetic piece is introduced into the modelled magnetic induction so as to bring about a modification of said magnetic induction distribution in order to increase, in the present case, the curvature of the induction lines at the entire sputtering surface 2 of target 1 or, in another way, to decrease the Bz value.

Figure 7 illustrates, by way of a graphic, a comparison between the values of this parameter, in absence or presence of a ferromagnetic piece, obtained along the considered right segment X-X′ at the target sputtering surface.

In the absence of ferromagnetic piece integrated to the target, it can be noted that $\frac{Bz}{B_{total}} = 0$ at a distance of 58 cm from the cathode central axis z. At this place, Bz is zero and the magnetic induction lines are parallel to the target surface.

However, the integration of a ferromagnetic piece with adequate shape and size, at a determined place of the magnetic induction allows the cancelling of this parameter at distances of 46 mm and 69 mm from the axis z and, as a consequence, the parallelism increase of the induction lines with respect to this target.

The modelling of the magnetic induction field modified by means of the above-mentioned ferromagnetic piece 10 perfectly shows, in figure 8, the parallelism increase of the induction lines at the target 1 sputtering surface 2 as compared to the induction lines at the same place of the target exempt of ferromagnetic piece such as represented in figure 4.

In addition, as shown and confirmed in figure 9, the chosen position, for integration of a ferromagnetic piece can be retained given that the magnetic induction remains higher than 100 gaus.

To such a place of sputtering target 1, a portion of this target is cut and extracted, portion which ends are located at 38 mm and 58 mm from axis z, respectively and the extracted volume is replaced by an equivalent volume

of a ferromagnetic piece which external surface is brought to the same level than the fitting surface of target 1 on cooling plate 3.

A computer simulation of the erosion, after cathodic sputtering of the target being part of the mounting so manufactured indicates in figure 10 a significant broadening of the erosion area illustrated by curve B as compared to the erosion illustrated by curve A recorded with an identical target exempt of inserted or juxtaposed ferromagnetic piece.

In the above-mentioned example, the ferromagnetic piece 10 is inserted in the lower part of the target. However, there exist other possibilities which depend among others on the properties of the material from which the target is made and of the working facilities.

EXAMPLE 2

As explained in Example 1, a mounting has been built which includes a sputtering target and a ferromagnetic piece inserted thereto, the mounting being configured so as to reduce the magnetic induction curvature and increase the parallelism of the magnetic induction lines at the target sputtering surface.

A simulation by computer technique of the erosion after cathodic sputtering of the target being part of the mounting so built indicates in figure 11, an extremely important broadening of the erosion area illustrated by curve D as compared to the erosion area illustrated by curve C, recorded with an identical target exempt of any inserted or juxtaposed ferromagnetic piece.

CLAIMS

1. Assembly intended to magnetron cathodic sputtering comprising a sputtering target, characterized in that it comprises, in addition to the sputtering target, at least once ferromagnetic piece inserted into that target or juxtaposed thereto and in that it is configured so as to modify the magnetic induction generated by the magnetron at the level of the target sputtering surface.

2. Assembly according to claim 1, characterized in that it is configured so as to modify the curvature of the magnetic induction lines.

3. Assembly according to claim 2, characterized in that it is configured so as to reduce the curvature of the magnetic induction lines and to increase the parallelism of these induction lines at the level of the target sputtering surface.

4. Assembly according to any of claims 1 to 3, characterized in that the ferromagnetic piece is completely or partially inserted into the target.

5. Assembly according to any of claims 1 to 4, characterized in that the inserted ferromagnetic piece is an indicator of the end of use of the target.

6. Process for manufacturing an assembly according to any of claims 1 to 5, characterized in that:

- <u>either</u>

a ferromagnetic piece is completely or partially inserted into the target after extraction, at a predetermined location of this target, of a portion thereof which is replaced by an equivalent portion of the said ferromagnetic piece

- <u>or</u>

a ferromagnetic piece is juxtaposed to the target at a predetermined location thereof.

7. Process according to claim 6, characterized in that the location of the ferromagnetic piece as well as it shape and size are predetermined thanks to a bidimentional or tridimentional modelling of the magnetic induction, obtained by means of a software-assisted computer technique.

8. Process for manufacturing an assembly according to any of claims 1 to 5, characterized in that it consists in :

a) determining, by measuring, the values of the total magnetic induction generated by the magnetron,
b) modelling, by means of a software-assisted computer technique, the magnetic induction from the magnetron physical characteristics,
c) comparing the modelled values of the magnetic induction with the previously measured values,
d) searching, in this modelled magnetic induction, the location, shape and size of a virtual ferromagnetic piece able to modify, in the desired manner, the magnetic induction at the level of the target sputtering surface,
e) optimizing the searche location, shape and size,
f) adding to the sputtering target and at the so determined location, a ferromagnetic piece corresponding to the shape and size data so defined, this being carried out either by insertion into that target or by juxtaposition thereto.

9. Process according to claim 8, characterized in that the searched location, shape and size of the ferromagnetic piece are optimized thanks to the parameter

$\frac{Bz}{B_{total}}$ when the modification of the magnetic induction consists in increasing the parallelism of the induction lines at the level of the target sputtering surface target.

10. Process for manufacturing an assembly according to claim 3 or 4, characterized in that it consists in :

a) determining, by measuring, the values of the total magnetic induction generated by the magnetron and of the vertical component of this magnetic induction,

b) modelling, by means of a software-assisted computer technique, the magnetic induction from the magnetron physical characteristics,

c) comparing the modelled values of the magnetic induction with the previously measured values,

d) searching, in this modelled magnetic induction, the location, shape and size of a virtual ferromagnetic piece able to reduce the magnetic induction lines and to increase the parallelism of these induction lines at the level of the target sputtering surface,

e) optimizing the searched location, shape and size, thanks to the parameter $\frac{Bz}{B_{total}}$,

f) adding to the sputtering target and at the so determined location, a ferromagnetic piece corresponding to the shape and size data so defined, this being carried out either by insertion into that target or by juxtaposition thereto.

11. Assembly whenever manufactured by using the process according to any of claims 6 to 10.

12. Assembly whenever manufactured according to any of claims 1 to 5 for the formation of a film deposit on a substrate by using a cathodic sputtering process.

13. Film deposit on a substrate, characterized in that it is formed by using a cathodic sputtering process starting from an assembly according to any of claims 1 to 5.

14. Method for uniformizing the erosion at a target sputtering surface intended to magnetron cathodic sputtering, characterized in that an assembly is used which comprises the said sputtering target and at least one ferromagnetic piece which is added thereto, by insertion or by juxtaposition at a predetermined location of that target, that assembly being manufactured by carrying out the following steps which consist in:

a) determining, by measuring, the values of the total magnetic induction generated by the magnetron and of the vertical component of that magnetic induction,

b) modelling by means of a software-assisted computer technique from the magnetron physical characteristics,

c) comparing the modelled values of the modelled magnetic induction with the previously measured values,

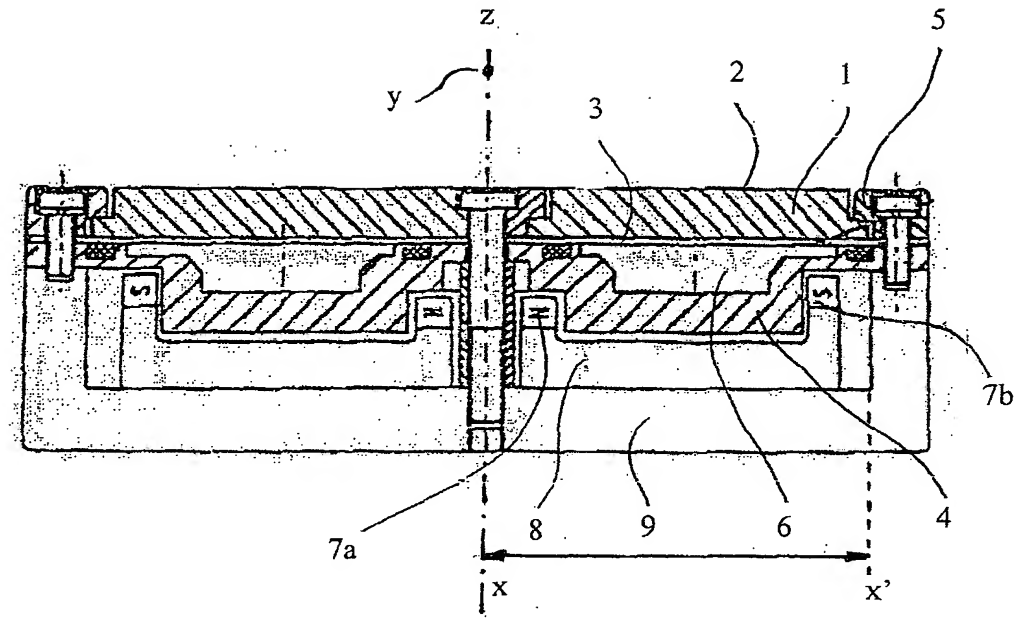
d) searching, in the modelled induction, the location, shape and size of a ferromagnetic piece able to reduce the curvature of the magnetic induction lines and to increase the parallelism of these induction lines at the level of the target sputtering surface,

e) optimizing the searched location, shape and size, thanks to the parameter $\frac{Bz}{B_{total}}$,

f) adding to the sputtering target and at the so predetermined location, a ferromagnetic piece corresponding to the shape and size data so defined, this

being carried out either by insertion into that target or by juxtaposition thereto.

1/5


z
y
5
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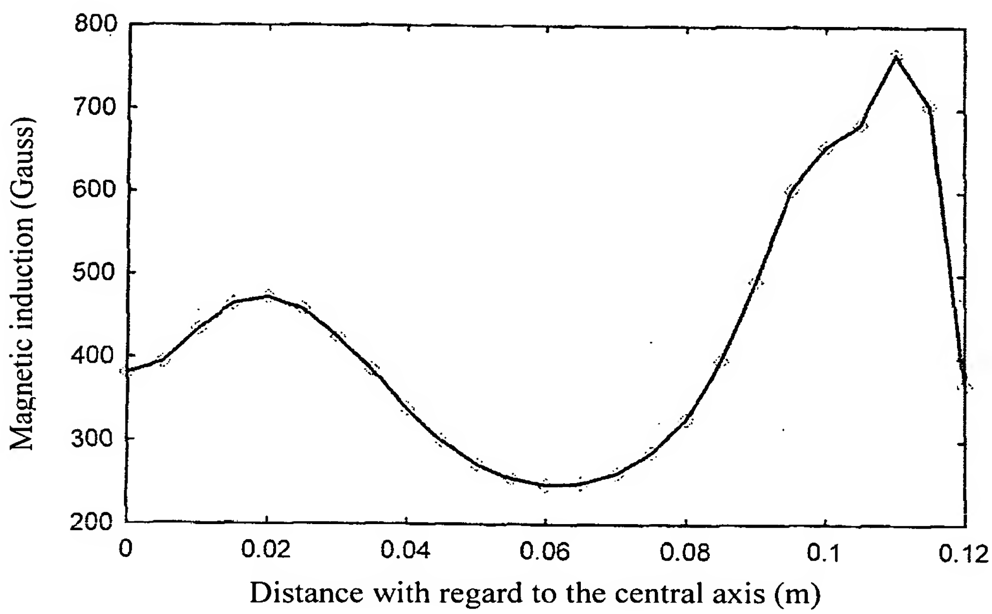
1
3
7b
7a
8
9
6
4
x
x'

Fig. 1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700
600
500
400
300
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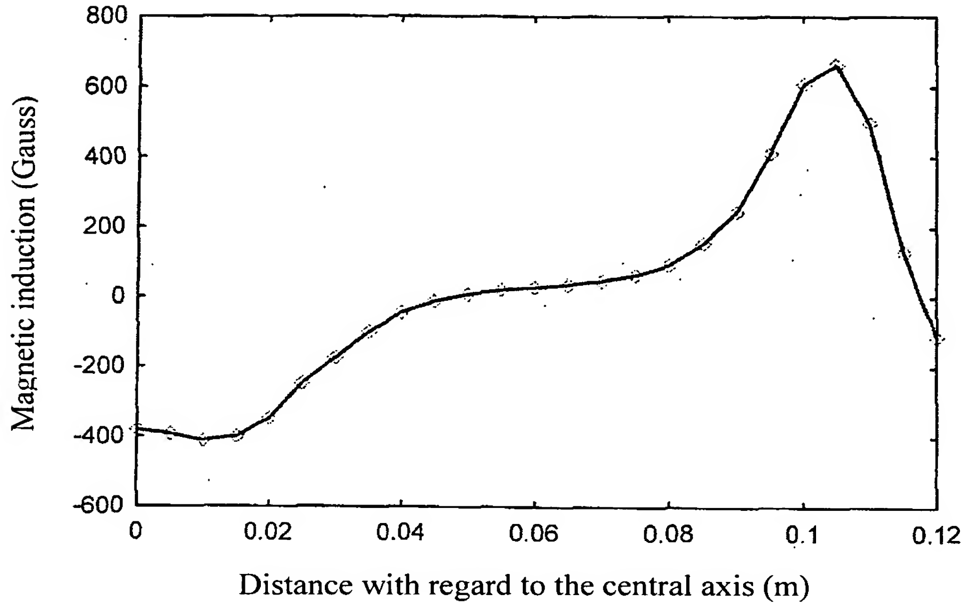
0.02
0.04
0.06
0.08
0.1
0.12
Distance with regard to the central axis (m)

Fig. 2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-400
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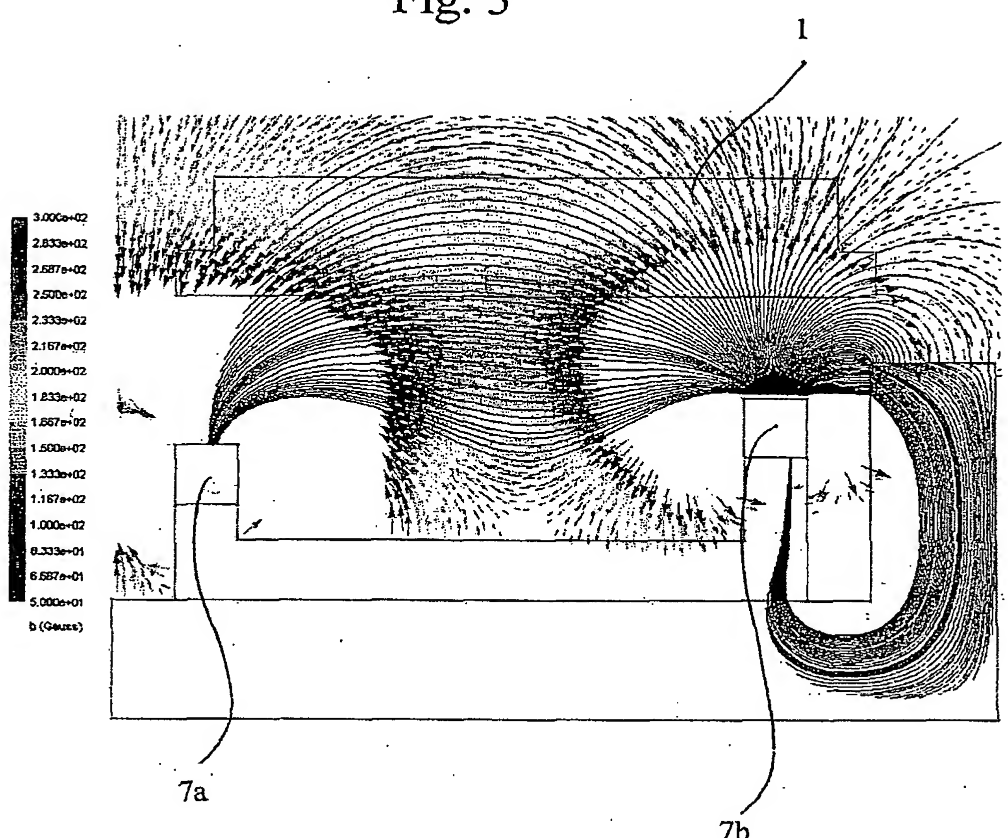
Magnetic induction (Gauss)
0
0.02
0.04
0.06
0.08
0.1
0.12
Distance with regard to the central axis (m)

Fig. 3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1.667e+02
1.500e+02
1.333e+02
1.167e+02
1.000e+02
8.333e+01
6.667e+01
5.000e+01
b (Gauss)
7a
7b

Fig. 4

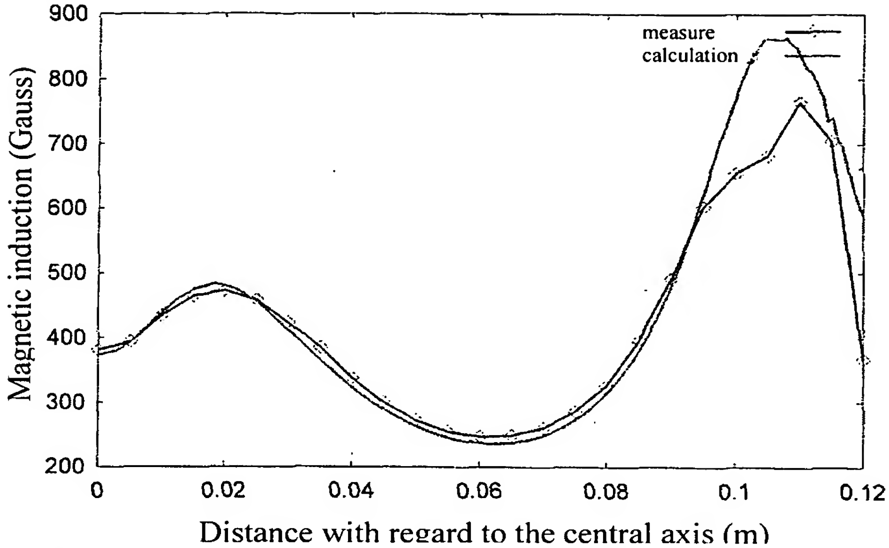

Fig. 5

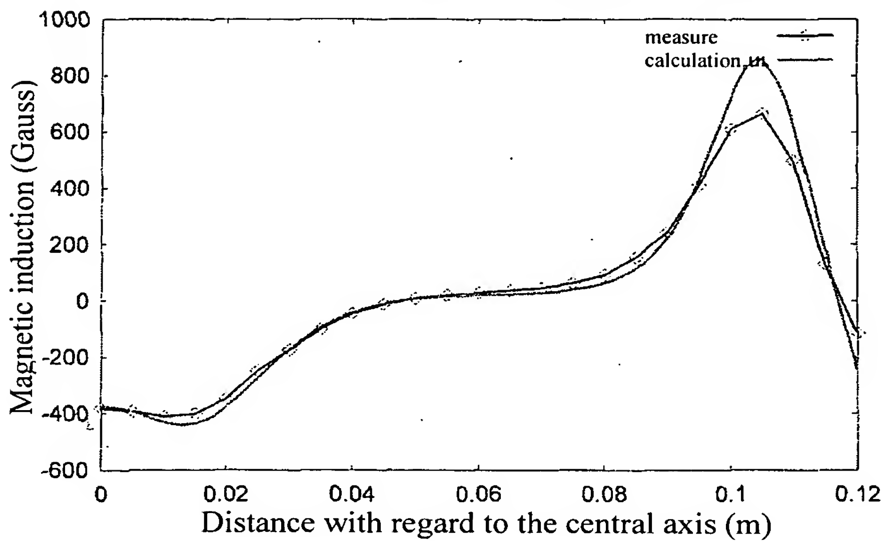

Fig. 6

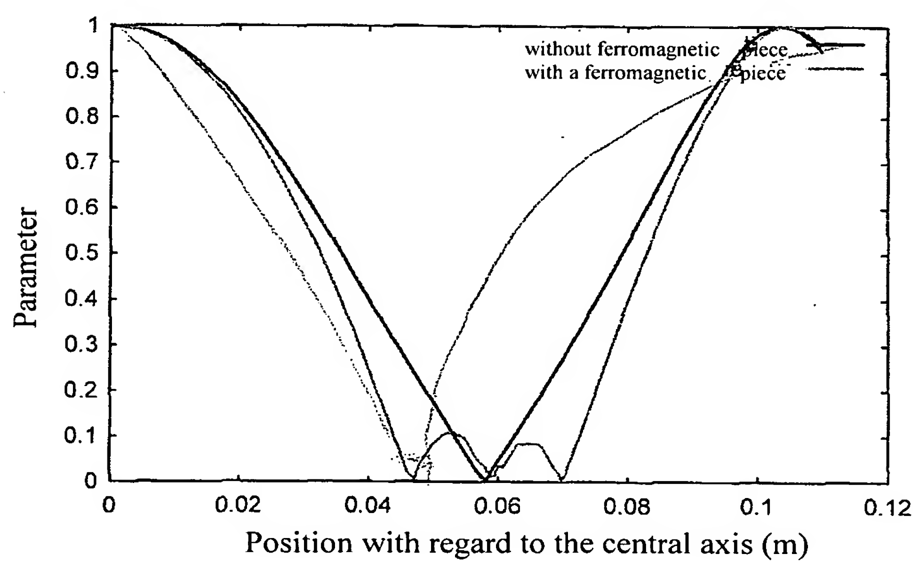

Fig. 7

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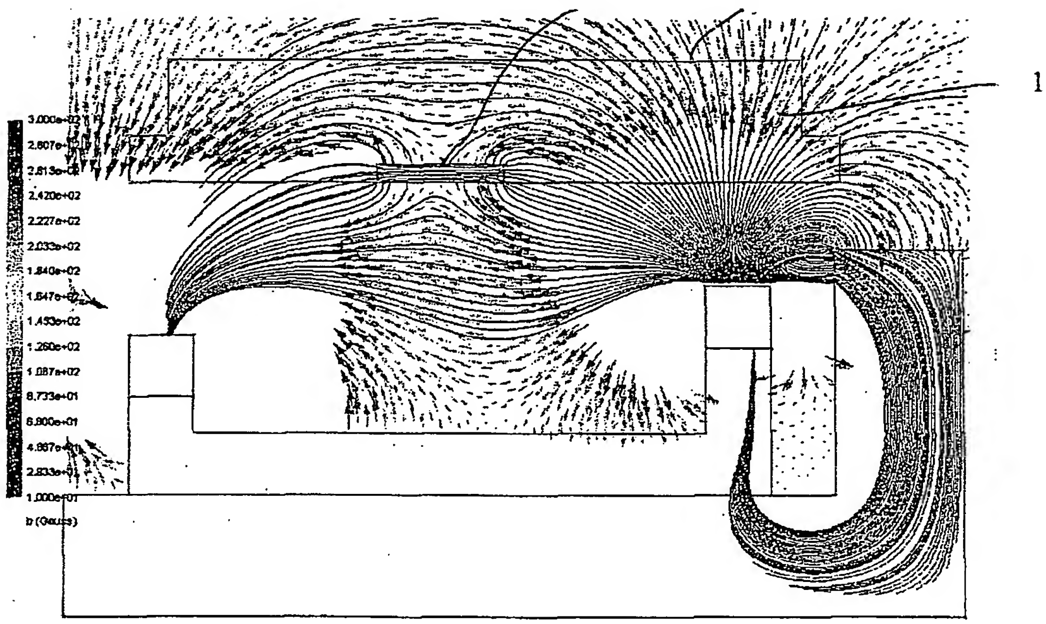

Fig. 8

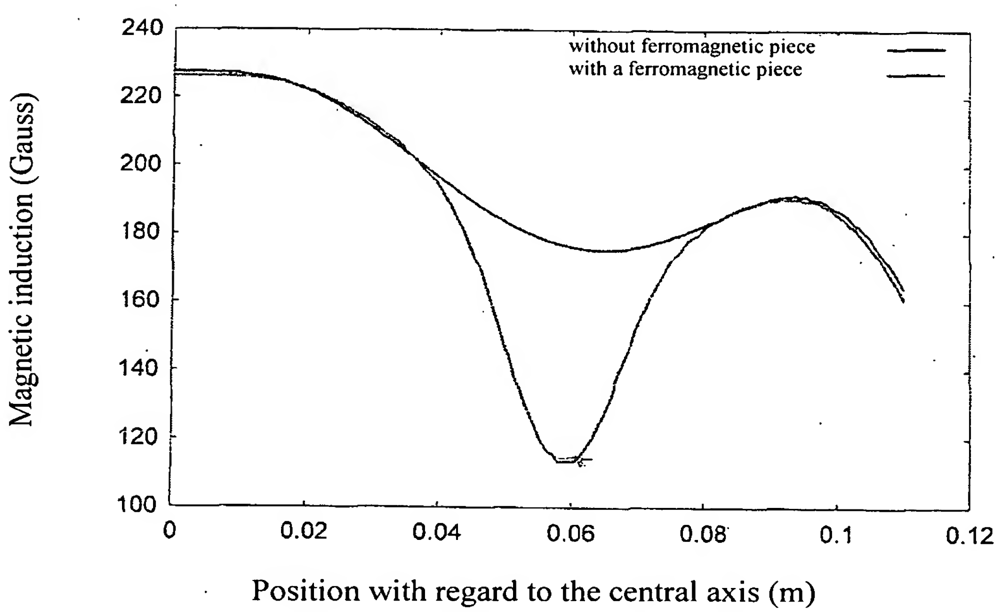

Fig. 9

5/5

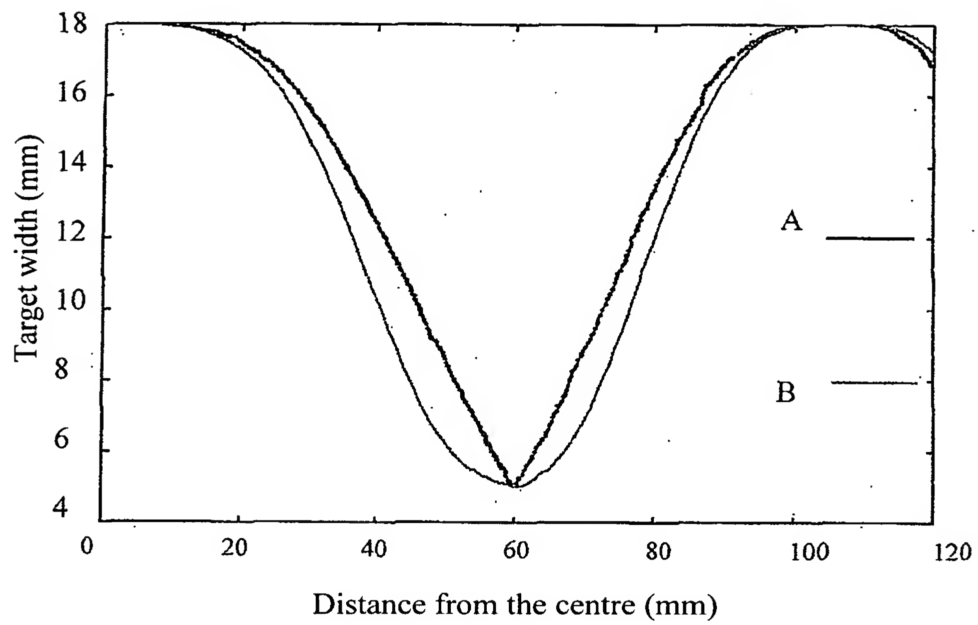

Fig. 10

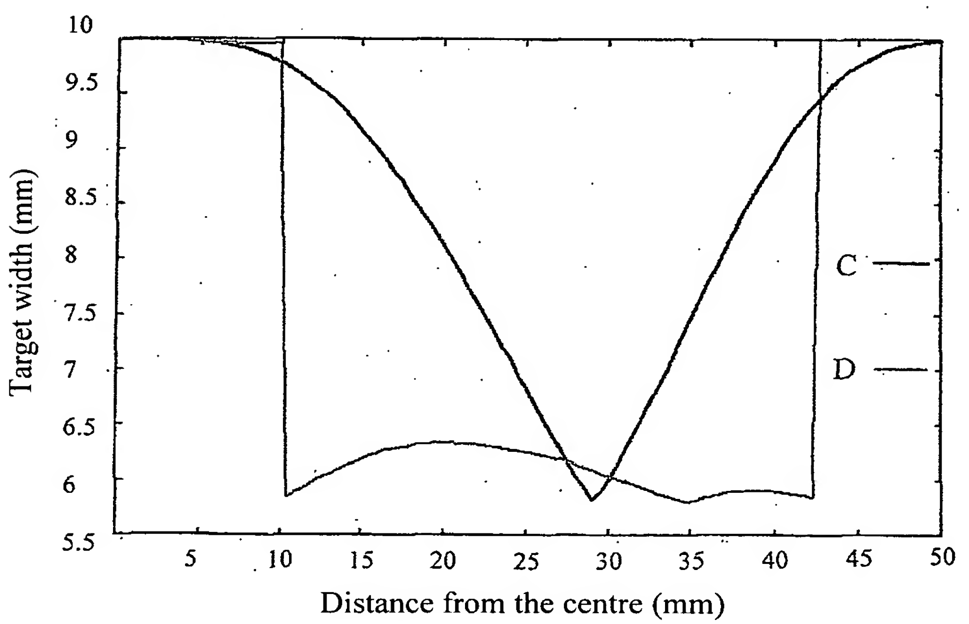

Fig. 11